



OPTICAL FIBER COMPONENT FOR SPOT SIZE  
TRANSITION AND METHOD OF MAKING THE SAME

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an optical fiber component for spot size transition and a method of making the same. In particular, the present invention relates to an optical fiber component for spot size transition ~~constituted~~ <sup>formed</sup> by splicing optical fibers with different core diameters and a method of making the same.

Description of the Related Art

~~An optical~~ <sup>Optical</sup> fiber communication networks <sup>have</sup> ~~has~~ been established rapidly ~~in accordance with development of a communication network~~ in recent years. The optical fiber communication network is basically ~~constituted~~ <sup>formed</sup> by splicing an outdoor optical fiber cable and an indoor apparatus or the like. In a situation in which demands for a communication network are increasing, high density packaging of optical fibers is inevitable. For example, in intra-machine wiring or the like, since the number of optical fibers <sup>inevitably</sup> ~~increases inevitably~~, saving of ~~a~~ space for containing the optical fibers and wiring of the optical fibers are ~~major~~ <sup>major</sup> matters of concern.

In order to contain and wire a large number of optical fibers in a limited space, it is necessary to bend the optical

fibers with a small radius of curvature. However, if the optical fibers are bent with a small radius of curvature, light easily leaks and ~~a~~ <sup>the</sup> quality of ~~a~~ <sup>the</sup> communication network as a whole is degraded.

Thus, in order to prevent light from easily leaking, even if the optical fibers are bent with a small radius of curvature, a so-called high  $\Delta$  optical fiber has started to be used, in which a refractive index difference between a core and a clad, that is, a relative refractive index difference  $\Delta$ , is larger than that of a single mode (SM) fiber which is ~~a~~ <sup>the</sup> conventional optical fiber used in ~~a~~ <sup>the</sup> communication networks. ~~A~~ <sup>The</sup> relative refractive index difference  $\Delta$  of the high  $\Delta$  optical fiber is 0.5 to 2.5%, whereas ~~a~~ <sup>the</sup> refractive index difference  $\Delta$  of the SM fiber is about 0.3%. If ~~a~~ <sup>the</sup> relative refractive index difference is increased in this way, since ~~a~~ <sup>the</sup> core diameter decreases, ~~a~~ <sup>the</sup> spot size also decreases. Here, the spot size is a parameter indicating spread of ~~the~~ <sup>the</sup> electromagnetic field distribution, that is, field distribution of a propagation mode in an optical waveguide, and is also ~~called a mode field diameter~~ <sup>referred to as</sup>.

However, such a high  $\Delta$  optical fiber is also eventually required to be spliced with the ordinary optical fiber which constitutes the optical fiber cable. As a result, a large transition loss is caused because mismatching occurs in ~~a spliced~~ <sup>splice</sup> ~~portion~~ <sup>between</sup> due to not only a difference of core diameters, but also a difference ~~of~~ <sup>between</sup> spot sizes. For example, when the SM fiber

and a high  $\Delta$  optical fiber with a spot size, which is about half of that of the ordinary optical fiber, are spliced in an abutting state using a connector or the like, a large transition loss of about 2 dB occurs due to ~~a~~ <sup>the</sup> difference <sup>in</sup> ~~of~~ spot sizes.

In order to eliminate such mismatching in a spliced portion of a SM fiber and a high  $\Delta$  optical fiber, there are known the following two techniques <sup>are known</sup>. ~~One is a~~ <sup>In one</sup> technique ~~for~~, after fusion-splicing the SM fiber and the high  $\Delta$  optical fiber, ~~heating~~ <sup>is heated</sup> the high  $\Delta$  optical fiber to thereby thermally diffuse a dopant in the fibers to expand <sup>the</sup> ~~a~~ core diameter such that an optimal spot size is obtained. The other ~~is a~~ <sup>involves</sup> technique ~~for~~ heating the high  $\Delta$  optical fiber to thereby thermally diffusing a dopant in the fiber and expand <sup>the</sup> ~~a~~ core diameter such that an optimal spot size is obtained and, then, cutting the part of the expanded core diameter to fusion-splice the high  $\Delta$  optical fiber with the SM fiber (e.g., see Japanese Patent No. 2618500).

In addition, there is also known a technique <sup>which involves</sup> ~~for~~ cutting the expanded part and mounting the high  $\Delta$  optical fiber to an optical connector such that a cut face thereof becomes an light incident and outgoing end face (e.g., see Japanese Patent No. 2619130).

~~Incidentally,~~ ~~the~~ <sup>The</sup> above-mentioned conventional techniques have problems ~~to be solve~~ as described below.

Japanese Patent No. 2618500 and Japanese Patent No. 2619130 describe a technique <sup>involving</sup> ~~for~~ expanding the core diameter

of the high  $\Delta$  optical fiber and, then, cutting the expanded part to splice the high  $\Delta$  optical fiber with the SM fiber. ~~However, in the case in which a cutting portion is decided such that an optimal spot size is obtained, since a transition loss is confirmed after splicing the high  $\Delta$  optical fiber and the SM fiber, it is difficult at the time of cutting to judge whether the cutting portion is always a portion where the optimal spot size is obtained. Thus, a highly accurate cutting technique and experiences are required.~~ where the location of the cut at location

In addition, in the case in which a core diameter is expanded by heating an optical fiber, the expanded core diameter may fluctuate depending upon heating conditions, and it is impossible to cut a large number of optical fibers always at the an identical position when core diameters of the optical fibers are expanded. Thus, it is difficult to steadily optimizes spot sizes of a the large number of optical fibers.

Moreover, in the case in which the high  $\Delta$  optical fiber is connected mounted to the optical connector with the core expanded portion as the incident and outgoing end face, since an advanced technique is required for grinding the incident and outgoing end face in order to obtain an optimal spot size, it is difficult to increase working efficiency. Thus, process management becomes complicated.

#### SUMMARY OF THE INVENTION

The present invention provides an optical fiber component, in which spot sizes of optical fibers with different core diameters are optimized ~~steadily~~ uniformly, and a method of making the same.

In order to solve the above-mentioned problems, the present invention ~~has constitutions as described below.~~ provides

~~First, a first invention is an optical fiber component for changing spot sizes of optical fibers with different core diameters, the optical fiber component for spot size transition~~ including ~~having arranged therein:~~ a large-diameter core optical fiber having a light incident and outgoing end face; a spliced portion in which the large-diameter core optical fiber and a small-diameter core optical fiber are fusion-spliced; a spot size transition portion in which a core diameter of the small-diameter core optical fiber is expanded in the vicinity of the spliced portion; and the small-diameter core optical fiber.

~~The~~ The ~~In addition, a refractive index profile in the spot size transition portion continuously changes~~ along ~~in the longitudinal~~ dimension ~~direction~~ of the optical fiber, and the spot sizes of the large-diameter core optical fiber and the small-diameter core optical fiber match in the spliced portion.

Further, ~~a~~ the relative refractive index difference in the spliced portion of the spot size transition portion is substantially identical with the ~~a~~ relative refractive index

difference of the large-diameter core optical fiber.

Moreover, the optical fiber component has the large-diameter core optical fiber, the spliced portion, the spot size transition portion, and the small-diameter core optical fiber co-arranged inside a ferrule.

The present invention further provides

~~Next, a second invention is~~ a method of making an optical fiber component for changing spot sizes of optical fibers with different core diameters, the method of making an optical fiber component for spot size transition comprising: fusion-splicing a large-diameter core optical fiber and a small-diameter core optical fiber to form a spliced portion, heating the vicinity of the spliced portion and thermally diffusing a dopant contained in the small-diameter core optical fiber to thereby expand the core diameter and form ~~for forming~~ a spot size transition portion, and then cutting at ~~an arbitrary position of~~ the large-diameter core optical fiber to provide a ~~set the~~ cut face as a light incident and outgoing end face, and arranging the large-diameter core optical fiber, the spliced portion, the spot size transition portion, and the small-diameter core optical fiber inside the optical fiber component.

When ~~In addition, in the case in which~~ the dopant is heated and thermally diffused to expand the core diameter of the small-diameter core optical fiber and form the spot size transition portion, the ~~a~~ refractive index profile in the spot size transition portion is continuously changed along ~~in~~ the longitudinal

dimension

~~direction~~ of the optical fiber, and the vicinity of the spliced portion is heated until spot sizes of the large-diameter core optical fiber and the small-diameter core optical fiber match in the spliced portion.

Further, when ~~in the case in which the dopant~~ is heated and thermally diffused to expand the core diameter of the small-diameter core optical fiber and form the spot size transition portion, heating is continued until the ~~a~~ relative refractive index difference of the spot size transition portion becomes substantially identical to the ~~with a~~ relative refractive index difference of the large-diameter core optical fiber in the spliced portion.

Moreover, when ~~in the case in which~~ the dopant is thermally diffused to expand the core diameter of the small-diameter core optical fiber and form the spot size transition portion, heating is performed while ~~a~~ transition loss of the spliced portion is monitored.

#### BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

schematic, partially in cross-section,  
Fig. 1 is a diagram showing an embodiment of the present invention;

illustrating steps in the  
Figs. 2A to 2C are diagrams ~~showing~~ an embodiment of ~~a~~ method of making an optical fiber component of the present invention; and

graph of versus frequency or  
Fig. 3 is a ~~diagram showing a transition loss of~~ an optical fiber component of the present invention.

#### DESCRIPTION OF THE PREFERRED EMBODIMENT

An embodiment of the present invention will be hereinafter with reference to described ~~using a specific example.~~

which  
No. 27 Fig. 1 is a longitudinal sectional view of an optical fiber component for spot size transition of the present invention. In Fig. 1, a large-diameter core optical fiber 1 comprises a cladding core 1a and a ~~clad~~ 1b. The core 1a is doped with Ge which is a dopant for increasing the refractive index, and the cladding ~~the clad~~ is pure quartz. This optical fiber 1 is the same as the a single mode fiber used in ~~for~~ an ordinary communication network, and the a relative refractive index difference thereof is 0.3%.

On the other hand, a small-diameter core high  $\Delta$  optical fiber 2 comprises a core 2a and a cladding ~~clad~~ 2b. The core 2a is also cladding doped with Ge, and the ~~the clad~~ is also pure quartz. The A doping amount of Ge doped in the core 2a is larger than the a doping amount of Ge doped in the core 1a of the optical fiber 1. Thus, the high  $\Delta$  optical fiber 2 is an optical fiber highly resistant against bending. The high  $\Delta$  optical fiber 2 is also a single mode fiber, and its a relative refractive index difference ~~thereof~~ is 0.5 to 2.5%. The A degree of the relative refractive index difference of the high  $\Delta$  optical fiber 2 depends upon a place where it is implemented. Thus, it is sufficient to select a most suitable



relative refractive index difference according to a laying environment thereof.

The optical fiber 1 and the high  $\Delta$  optical fiber 2 are fusion-spliced in ~~a~~ spliced portion 3. Then, ~~a~~ <sup>the</sup> core diameter of the high  $\Delta$  optical fiber 2 in the vicinity of this spliced portion 3 is expanded to form a spot size transition portion 4. The spot size transition portion 4 is a portion in which the vicinity of the spliced portion 3 <sup>has been</sup> ~~is~~ heated to diffuse Ge doped in the core 2a of the high  $\Delta$  optical fiber 2 into the ~~cladding~~ <sup>cladding</sup> 2b to expand the core diameter of the core 2a. <sup>The</sup> ~~A~~ refractive index profile continuously changes <sup>along</sup> ~~in~~ the longitudinal <sup>dimension</sup> ~~direction~~ of the high  $\Delta$  optical fiber 2 in the spot size transition portion 4. In addition, <sup>the</sup> relative refractive index differences of the optical fiber 1 and the high  $\Delta$  optical fiber 2 are substantially identical in the spliced portion 3. With such <sup>component</sup> ~~a~~ constitution, increase in ~~a~~ transition loss due to mismatching of spot sizes between the optical fiber 1 and the high  $\Delta$  optical fiber 2 is eliminated.

Further, both the spliced portion 3 and the spot size transition portion 4 are ~~arranged so as to be~~ located inside ~~The large-diameter core optical fiber 1 is arranged on~~ a ferrule 5. <sup>On</sup> ~~a~~ light incident and outgoing side in the ferrule 5, ~~the large-diameter core optical fiber 1 is arranged~~ and a light incident and outgoing end face 6 is formed. Since the optical fiber 1 has a relative refractive index difference identical with that of an optical fiber used in the ordinary

communication network, increase in a transition loss is never caused even if, for example, the optical fiber 1 is spliced with the optical fiber used in a communication network in the part of the light incident and outgoing end face 6.

In Here, ~~in~~ this embodiment, the optical fiber <sup>core of the</sup> ~~with Ge~~ <sup>is doped</sup>, which is a dopant for increasing a refractive index, ~~doped in the core is described~~ as an example. However, the dopant is not limited to Ge, and other dopants may be adopted. <sup>Alternatively,</sup> ~~In addition,~~ ~~for example, the same constitution can be adopted in an optical fiber with F, which is a dopant for decreasing a refractive index, doped in a clad.~~ <sup>which decreases</sup> ~~F for example, may be~~ <sup>into the cladding.</sup>

A Next, <sup>for</sup> ~~a method of~~ making an optical fiber component for spot size transition <sup>, in accordance with</sup> ~~of the present invention will be described.~~ <sup>now</sup> ~~with reference to~~ <sup>wherein features</sup> Figs. 2A to 2C are diagrams for explaining a process of the ~~method of making an optical fiber component for spot size transition of the present invention.~~ Note that portions <sup>are</sup> ~~will be~~ identical with those described in Fig. 1 ~~will be~~ denoted by the identical reference numerals. In Fig. 2A, the optical fiber 1 is a single mode fiber <sup>, as</sup> ~~used in an ordinary communication network~~ with a relative refractive index difference of 0.3%, in which the core 1a is doped with Ge and the <sup>cladding</sup> ~~clad~~ 1b is a pure quartz. In addition, the high  $\Delta$  optical fiber 2 is also a single mode fiber with a relative refractive index difference of 0.5 to 2.5%, in which the core 2a is doped with Ge and the <sup>cladding</sup> ~~clad~~ 2b is a pure quartz. The optical fiber 1 and the high  $\Delta$  optical

fiber 2 are fusion-spliced with end faces thereof abutted against ~~with~~ each other.

Note that external diameters of the optical fiber 1 and the high  $\Delta$  optical fiber 2 may be identical or may be different. In this embodiment, the splice of optical fibers with an identical external diameter is described. However, for example, one of the optical fibers may be a conventional optical fiber with an external diameter of 125  $\mu\text{m}$  and the other may be S-Tylus (registered trademark of Showa Electric Wire & Cable Co., Ltd.) in which an optical fiber with an external diameter of 115  $\mu\text{m}$  is covered with non-releasable resin.

When the optical fiber 1 and the high  $\Delta$  optical fiber 2 are fusion-spliced, the external diameters thereof are identical in the spliced portion 3. However, the core diameters thereof are different from each other. Actually, the core diameter 2a of the high  $\Delta$  optical fiber 2 is slightly expanded by heat at the time of fusion-splicing, which is insufficient ~~to achieve~~ <sup>The</sup> for the object of the present invention. ~~A~~ <sup>The</sup> length L of a spot side transition portion required for the present invention is 1 to 2 mm when, for example, ~~a~~ <sup>the</sup> ratio  $\gamma$  of ~~a~~ <sup>the</sup> core diameter of ~~a~~ <sup>the</sup> large-diameter core optical fiber ~~and a~~ <sup>to the</sup> core diameter of ~~a~~ <sup>the</sup> small-diameter core optical fiber is assumed to be 2, e.g., in the case in which the diameters are 10  $\mu\text{m}$  and 5  $\mu\text{m}$ , respectively.

In Fig. 2 after fusion-splicing the optical fiber 1 and

the high  $\Delta$  optical fiber 2, the vicinity of the spliced portion 3 is heated by heating means 7 such as a burner, a heater, or electric discharge. ~~The~~ <sup>The</sup> area to be heated is about several millimeters. ~~Conditions~~ <sup>Conditions</sup> However, it is sufficient to decide conditions such as a heating range, a heating time, and a heating temperature <sup>are</sup> ~~are~~ appropriately <sup>set</sup> ~~set~~ according to <sup>the</sup> ~~a~~ size of a core diameter to be expanded. At this point, it is preferable to continuously change <sup>the</sup> ~~a~~ refractive index profile in the spot size transition portion 4 in the longitudinal direction of the high  $\Delta$  optical fiber 2, and <sup>to</sup> ~~to~~ heat the spliced portion 3 until spot sizes of the optical fiber 1 and the high  $\Delta$  optical fiber 2 match in the spliced portion 3. In addition, it is advisable to expand the core 2a of the high  $\Delta$  optical fiber 2 until <sup>the</sup> ~~relative~~ refractive index differences of the optical fiber 1 and the high  $\Delta$  optical fiber 2 become substantially identical, <sup>to</sup> ~~to~~ form the spot size transition portion 4. In order to make the spot sizes of the optical fiber 1 and the high  $\Delta$  optical fiber 2 match or the relative refractive index differences of the optical fiber 1 and the high  $\Delta$  optical fiber 2 substantially identical, it is advisable to <sup>continuously</sup> ~~always~~ monitor <sup>in</sup> ~~a~~ transition loss of the spliced portion 3 during heating and <sup>to</sup> ~~stop~~ the heating at the point when the transition loss of the spliced portion 3 is minimized. Note that in the case of the above-mentioned S-Tylus, since <sup>the</sup> ~~an~~ external diameter thereof is smaller than that of the conventional optical fiber, thermal conductivity is increased,

the effect of

~~an expansion effect of a~~ core diameter is improved, and working efficiency is improved.

Then, as shown in Fig. 2C, an arbitrary position of the optical fiber 1 is cut by a cutting blade 8 to form a light incident and outgoing end face 6. It is sufficient to cut the optical fiber 1 to ~~in a part of~~ an appropriate length such that both the spliced portion 3 and the spot size transition portion can be arranged 4 ~~are placed~~ in a ferrule. Thereafter, all of the optical fiber 1, the spliced portion 3, the spot size transition portion 4, and the high  $\Delta$  optical fiber 2 are arranged inside the ferrule 5 shown in Fig. 1, and then the light incident and outgoing end face 6 is ground form ~~is grinded to constitute~~ the optical fiber component of the present invention. This optical fiber component is mounted to, for example, a not-shown optical connector and used connecting, by splicing ~~for connector splicing or the like of~~ an ordinary optical fiber and a high  $\Delta$  optical fiber.

Fig. 3 shows the ~~a~~ result of measuring the ~~a~~ transition loss of the spliced portion 3. The result indicates ~~a loss at the time~~ ~~when a transition loss is monitored~~ during heating of the spliced portion 3 in expanding ~~a~~ core diameter, and the heating is stopped in time reaches a minimum. The at the point when the transition loss ~~becomes the lowest. A~~ heating temperature was ~~is~~ 1400 °C, and a heating time is several minutes to several tens minutes, although the heating time fluctuates slightly because it is continued ~~a time~~ until the transition reaches a minimum ~~loss becomes the lowest. According to~~ Fig. 3, shows an average value

~~for~~ of the transition loss ~~is~~ <sup>of</sup> 0.025 dB, and a maximum value ~~thereof~~ <sup>of</sup> is 0.06 dB, which are extremely low <sup>as</sup> compared with a transition loss due to ~~mismatching of spot sizes in the past.~~ <sup>previous</sup>

In other words, the present invention attempts to solve the problems ~~in that~~ <sup>encountered</sup> when a core diameter of a high  $\Delta$  optical fiber ~~is~~ <sup>was</sup> expanded, and ~~then~~ <sup>was then</sup> the expanded portion ~~is~~ cut to fusion-splice or connector-splice the high  $\Delta$  optical fiber with a SM fiber used in a communication network, <sup>i.e. the</sup> a portion where the expanded portion of the core diameter ~~is cut~~ <sup>was</sup> ~~is not stabilized,~~ <sup>and therefore</sup> a transition loss ~~fluctuates,~~ <sup>varies</sup> and a highly accurate cutting technique or grinding technique ~~is~~ <sup>was</sup> required. <sup>In the solution to the foregoing</sup> ~~For this purpose,~~ <sup>problem, i.e. the present invention,</sup> first, the ordinary optical fiber and the high  $\Delta$  optical fiber with different core diameters are fusion-spliced, then the core diameter of the small-diameter core high  $\Delta$  optical fiber is expanded to form an appropriate spot size transition portion, <sup>a cut is made at</sup> and then an arbitrary position <sup>on</sup> of the large-diameter core optical fiber ~~is cut to~~ <sup>form</sup> ~~constitute~~ an optical fiber component. The large-diameter core optical fiber used in the optical fiber component of the present invention has a core diameter identical with that of the optical fiber used in a communication network, and this core diameter is uniform <sup>along its length.</sup> ~~in the longitudinal direction.~~ Thus, an advanced technique is not required for <sup>the location</sup> ~~deciding~~ <sup>where the cut is to be made. The</sup> ~~cutting portion.~~ <sup>In addition,</sup> the large-diameter core optical fiber is arranged on <sup>the</sup> ~~a~~ light incident and outgoing end face side. Thus, since optical fibers of the same type as the optical

fiber used in a communication network are spliced, for example, even in the case in which the SM optical fiber and the high  $\Delta$  optical fiber are spliced by an optical connector or the like, increase in ~~a~~ transition loss is minimized ~~can be suppressed~~, and an optical fiber component with stable characteristics is obtained.

According to the optical fiber component for spot size transition and the method of making the same of the present invention as described above, an optical fiber component having an appropriate spot size transition portion can be manufactured without requiring an advanced technique. In addition, an optical fiber component, which does not ~~cause~~ increase ~~in a~~ transition loss, even in the case in which a high  $\Delta$  optical fiber is spliced with a SM optical fiber used in a communication network, can be provided.

## ABSTRACT OF THE DISCLOSURE

A large-diameter core optical fiber and a small-diameter core high  $\Delta$  optical fiber are fusion-spliced, and the vicinity of a spliced portion is heated to expand <sup>the</sup> a core diameter of ~~a core of~~ the high  $\Delta$  optical fiber and form a spot size transition portion, whereby spot sizes of the optical <sup>fibers</sup> fiber and the high  $\Delta$  optical fiber are matched and relative refractive index differences thereof are made substantially identical. Subsequently, an arbitrary position of the optical fiber is <sup>at an arbitrary position</sup> cut ~~such that~~ the spliced portion and the spot size transition portion are placed inside a ferrule, <sup>with large diameter core</sup> and the optical fiber is arranged on a light incident and outgoing end face side of the ferrule to form an optical fiber component. ~~It is advisable to expand the~~ <sup>The</sup> core diameter <sup>is expanded</sup> of the core while monitoring a transition loss of the spliced portion. ~~In this way, an optical fiber component having an optimal spot size transition portion can be manufactured without requiring an advanced technique, and an optical fiber component, which does not cause increase in a transition loss. even in the case in which a high  $\Delta$  optical fiber is spliced with an ordinary optical fiber used in a communication network, can be provided.~~ <sup>to obtain</sup>